Components in wireless technologies (5XTC0)

Lab 1: Computer-aided circuit simulation tool QUCS

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Electrical Engineering

Agenda

- Why QUCS?
- Download & installation of QUCS
- Instructions
- Exercises using QUCS

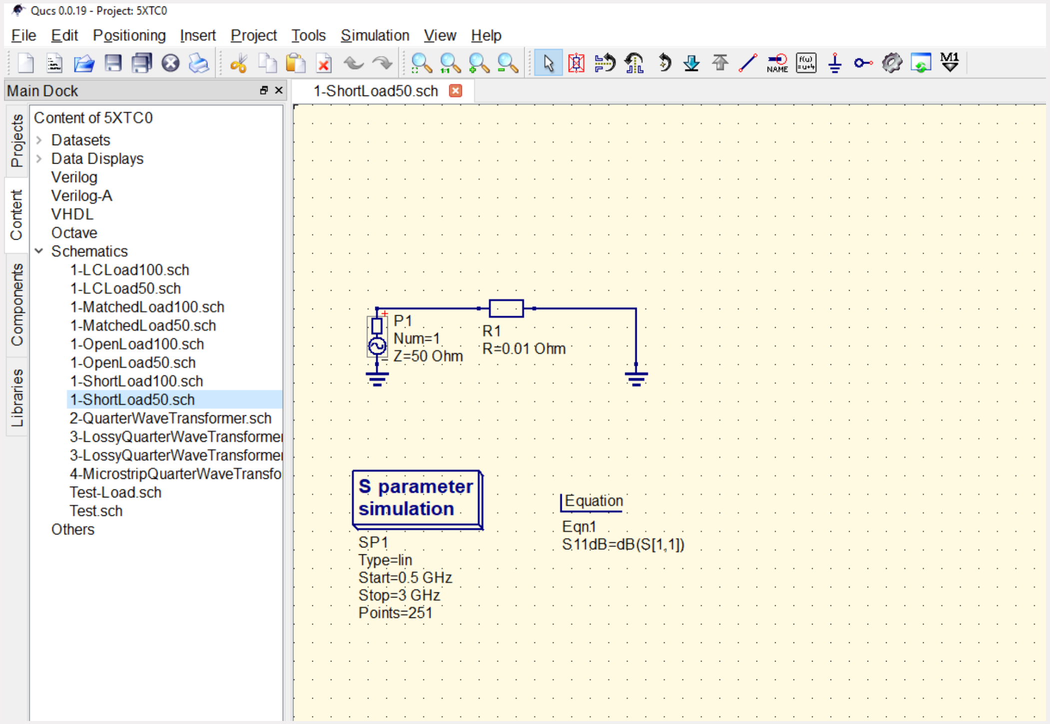


Figure 1: QUCS

Why QUCS?

QUCS (Quite Universal Circuit Simulator) is open-source and free of use circuit simulator. It has a similar interface and functionality as the commercial software ADS (Advanced Design System) from Keysight.

Ideal for learning how to use a (RF) circuit simulator.

It has some bugs/quirks.
Example: press ENTER after entering a value instead of clicking away.

There are a couple forks of the project (QUCS-S, QucsStudio etc). Feel free to use another version. We use QUCS v0.0.19 in this course for explanations.

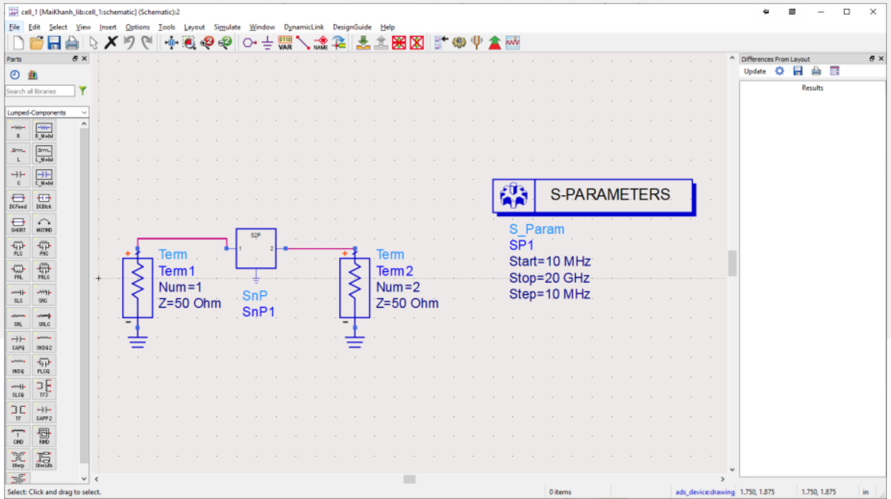
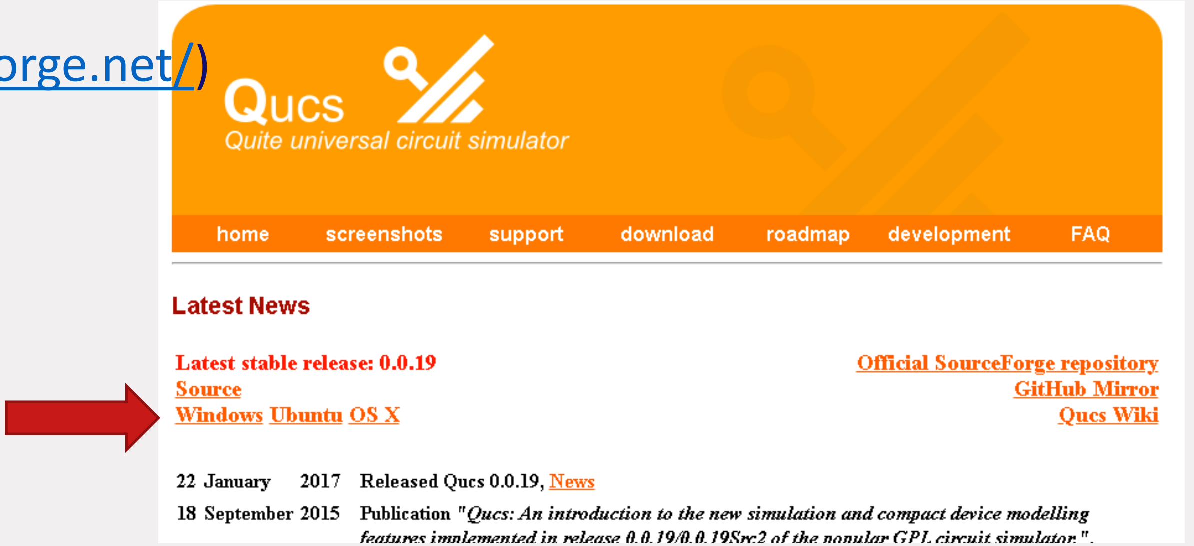


Figure 2: ADS Schematic view

Downloading QUCS v0.0.19

- Windows:
  - from TU/e (LINK)
  - from SourceForge (http://qucs.sourceforge.net/)
- Ubuntu or Mac OS X
  - from SourceForge (http://qucs.sourceforge.net/)



Installing / Starting QUCS

- Windows
  - Unzip and start QUCS via "qucs.bat" in the root folder of QUCS. When starting Qucs.exe in the binary folder, the simulator can crash for an unclear reason(!)
- Ubuntu
  - Install .deb package and start shortcut
- Mac
  - Install .pkg package and start shortcut

Questions?

If you have issues downloading or installing QUCS, please contact

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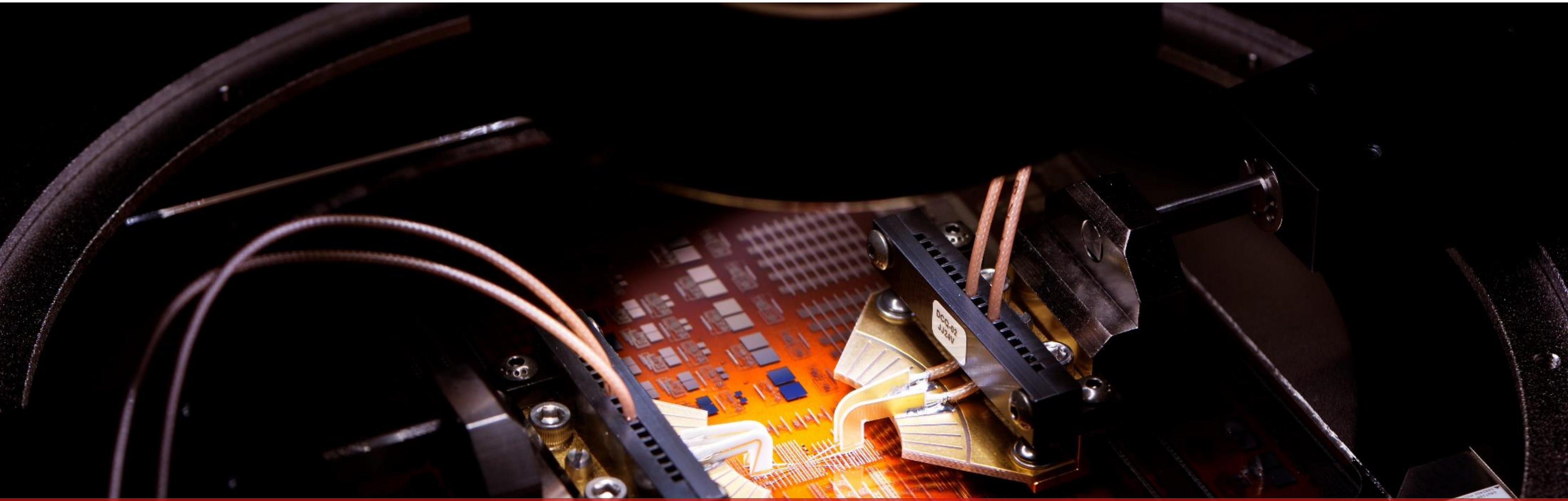


Lab 1: Computer-aided circuit simulation tool QUCS

Exercises

Instructions

You can work in pairs if you like or work solo.

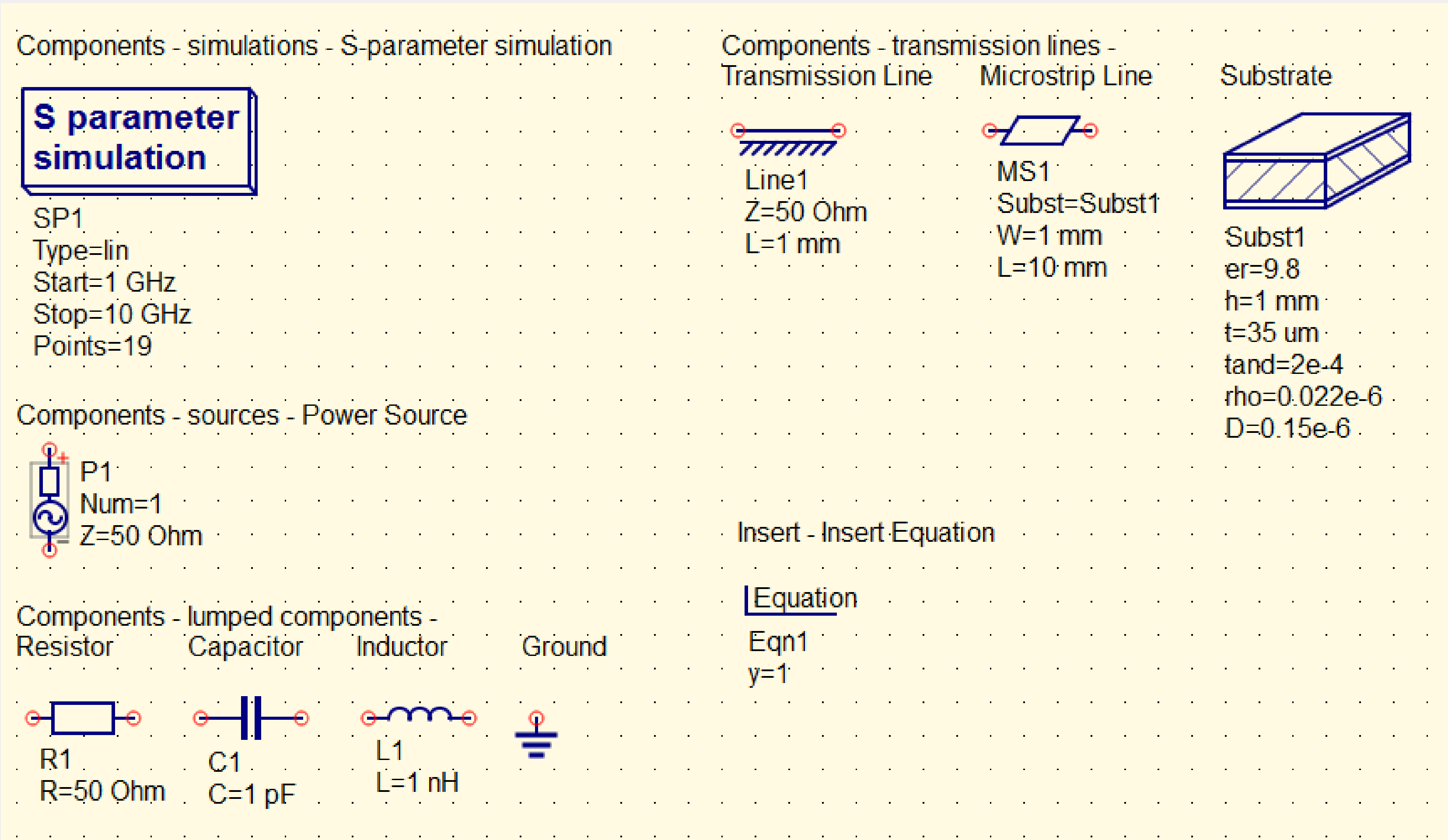
Use the template answer document to write the results and copy-paste the schematics and graphs in. Explain then the results in your own words.

When you are done, save the document with name:
5XTC0 - LAB1 - STUDENTNUMBER & NAME.docx

Then upload the document on CANVAS.

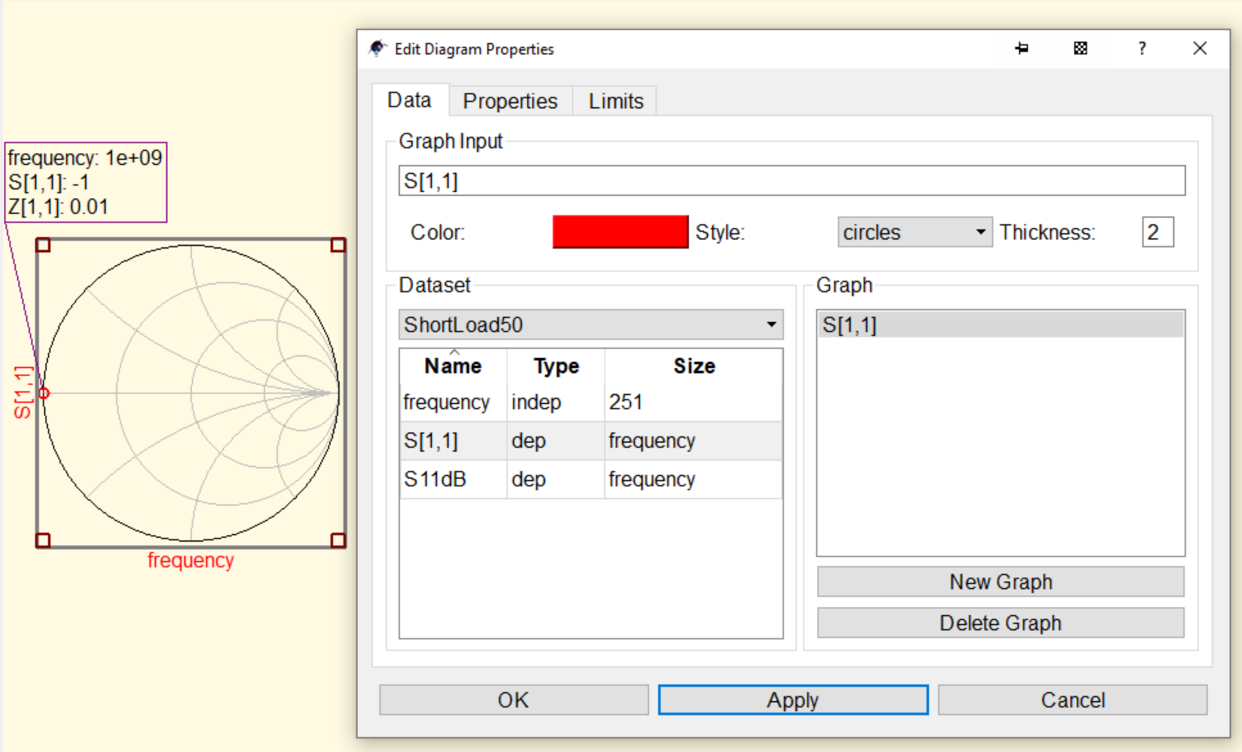
Time during this lab should be sufficient. Submission deadline is set to 23:59 tomorrow (14-02-2025).

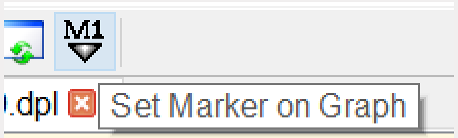
Symbols that you should use in these exercises



Tips & Tricks

How to make a dot visible in Smith Chart: Use “Circles” and set “Thickness” to 2



Place the marker via 

and click on the trace

Select the marker and press the arrow buttons on your keyboard to change the frequency of the marker

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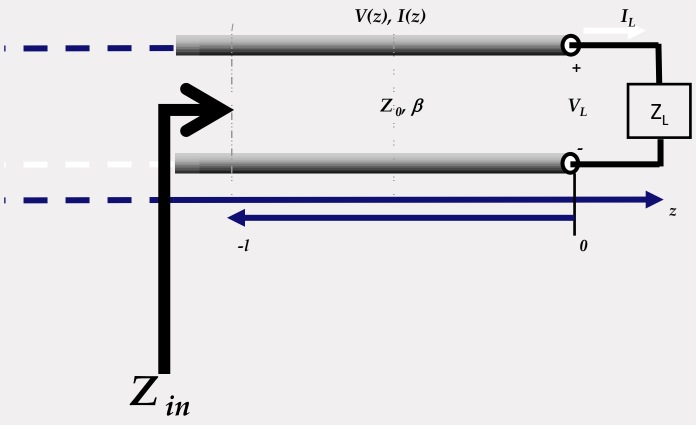
Equations to use for transmission lines

Terminated transmission line equations (week 1):

$$\Gamma(z=0) = \frac{V_0^-}{V_0^+} = \frac{Z_L - Z_0}{Z_L + Z_0}$$



$$\Gamma(z=-l) = \frac{V_0^- e^{-j\beta l}}{V_0^+ e^{j\beta l}} = \Gamma e^{-2j\beta l},$$

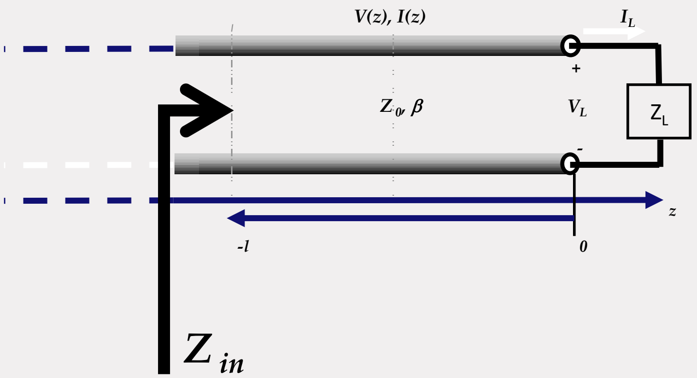
$$\Gamma = \Gamma(z=0).$$

$$Z_{in}(z=-l) = Z_0 \frac{Z_L + jZ_0 \tan \beta l}{Z_0 + jZ_L \tan \beta l}$$

$$\lambda = \frac{2\pi}{\beta}, f = \frac{c}{\lambda}$$

Exercise 1 – Transmission lines

Simulate in QUCS using S-parameters:



a. Short-circuit load (Z_0 = 50 Ohm)
b. Short-circuit load (Z_0 = 100 Ohm)
c. Open-ended load (Z_0 = 50 Ohm)
d. Open-ended load (Z_0 = 100 Ohm)
e. Matched load (Z_0 = 50 Ohm, Z_L = 50 Ohm)
f. Matched load (Z_0 = 100 Ohm, Z_L = 100 Ohm)

g. LC lumped elements (resonator) and 50 Ohm resistor as load (Z_0 = 50 Ohm) (resonating frequency = 1 GHz)

h. LC lumped elements (resonator) and 100 Ohm resistor as load (Z_0 = 100 Ohm) (resonating frequency = 1 GHz)

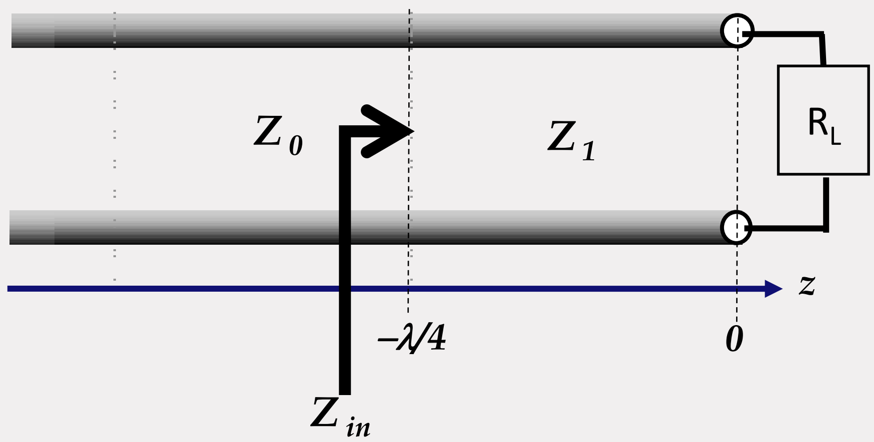
Output data:

S_{11} (=Γ) versus frequency (0.5GHz – 3.0GHz; 251 points)

Linear, Logarithmic (dB) and Smith chart

Explain the results of these simulations

Equations for quarter-wave transformer



Input impedance at $z=-\lambda/4$:

$$Z_{in} = Z_1 \frac{R_L + jZ_1 \tan\beta l}{Z_1 + jR_L \tan\beta l}$$

Now $\beta l = (2\pi/\lambda)(\lambda/4) = \pi/2$

$$Z_{in} = \frac{Z_1^2}{R_L}$$ ⟹ $\Gamma = 0$ if $Z_1 = \sqrt{Z_0 R_L}$

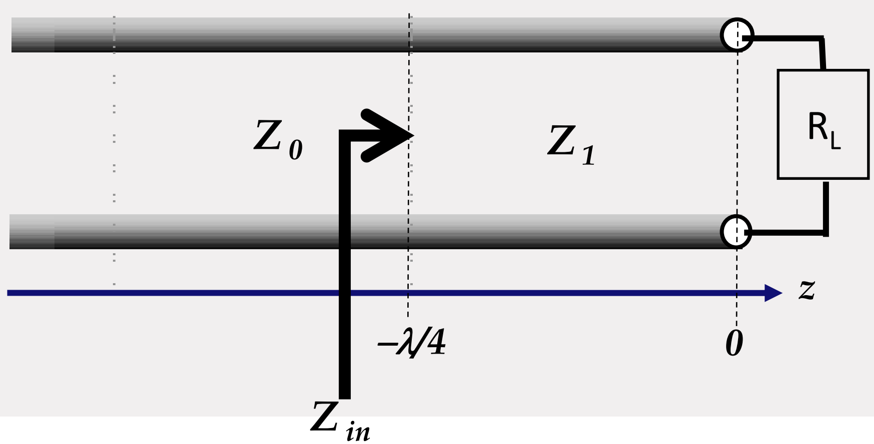
Exercise 2 – Quarter-wave transformer

Consider a load resistance of $Z_L = R_L = 100$ Ohm to be matched to a 50 Ohm line with a quarter-wave transformer. Design a quarter-wave transformer optimized for f=1 GHz. Assume a lossless transmission line.

Plot the reflection coefficient Γ (=S_{11}) (linear and in dB) versus frequency. Frequency range: 0.5GHz – 10 GHz with 1051 points.

Note: length is in meter. If you type "l = 100" QUCS assumes l = 100 m

and if you type "l = 100 m" or l =100 mm" QUCS assumes l = 100 mm.

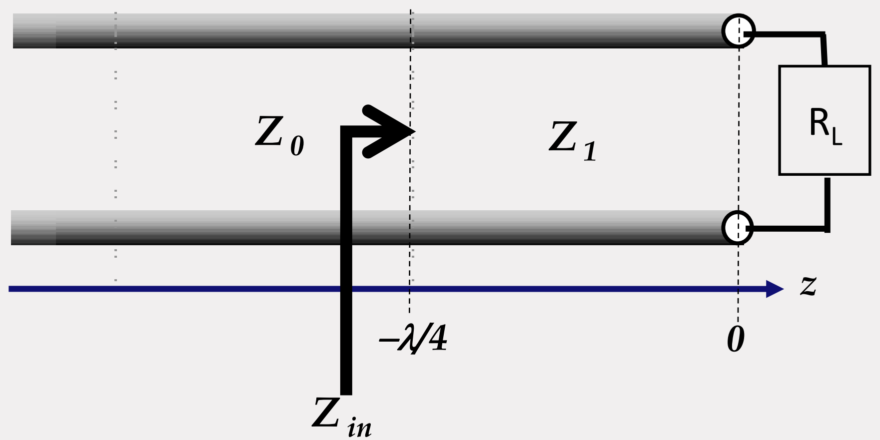


Exercise 3 – Lossy Quarter-wave transformer

Use the same parameters as found in Exercise 2. In this case the line is lossy. Consider 2 situations:

- attenuation of line = 1 dB/m (in terms of power).
- attenuation of line = 50 dB/m (in terms of power).

Determine Γ (=S_{11}) in dB versus frequency. Explain the results

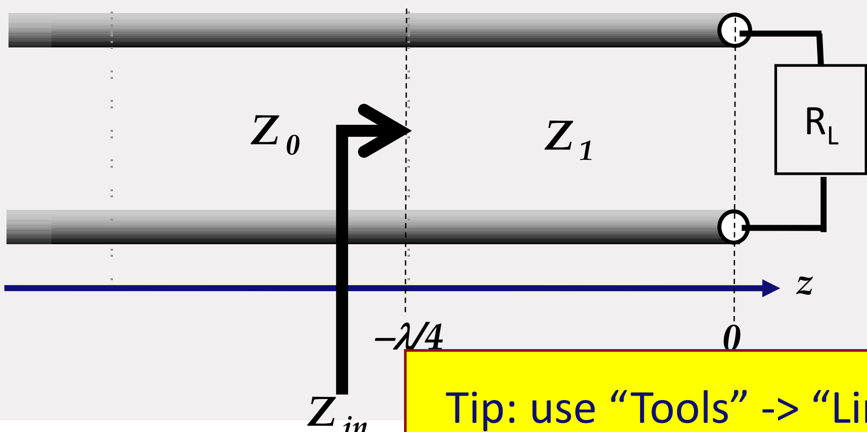


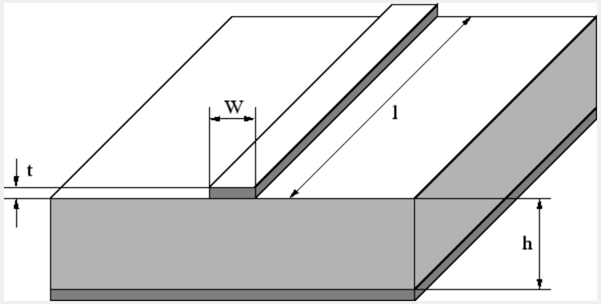
Exercise 4 – microstrip Quarter-wave transformer

Now use a real microstrip transmission line in your transformer. The microstripline is printed on a PCB with relative permittivity ε_r=4.2, loss tangent=0.001 and *h*=1.6 mm, *t*=35 µm. Consider a load resistance of $Z_L=R_L=100$ Ohm to be matched to a 50 Ohm line with a quarter-wave transformer.

To do:

1. Determine the width and length of the microstrip transformer optimized for *f*=1 GHz.
2. Plot the reflection coefficient Γ (=S_{11}) versus frequency.
3. Why is L shorter as compared to the ideal Transmission line case?





Tip: use “Tools” -> “Line calculation” to determine W,L

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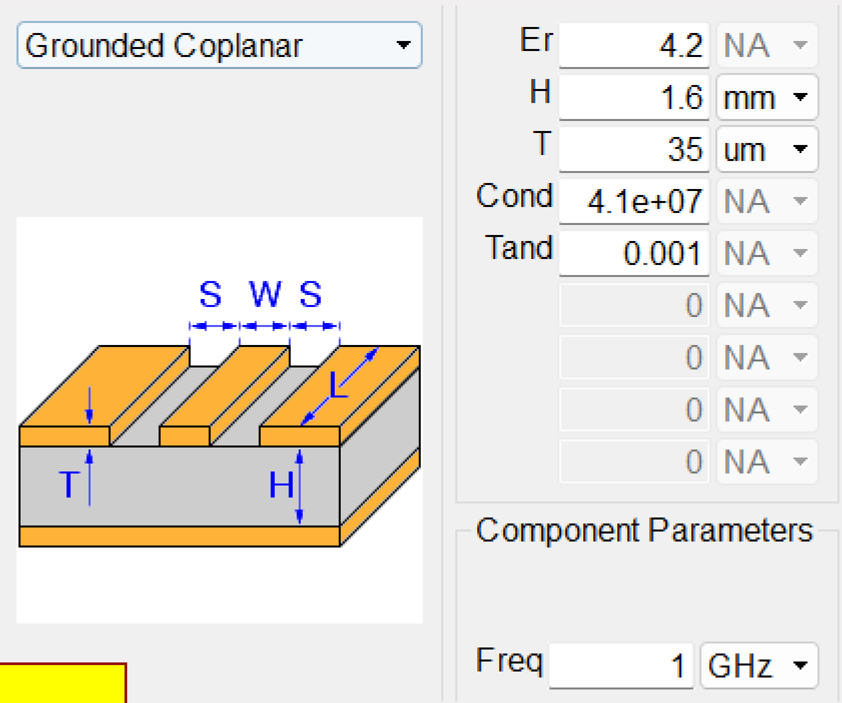
Exercise 5 – Co-planar Quarter-wave transformer

Now use a real grounded co-planar transmission line in your transformer. The coplanar line is printed on a PCB with relative permittivity ε_r=4.2, loss tangent=0.001 and h=1.6mm, t=35 μm. Consider a load resistance of $Z_L=R_L=100$ Ohm to be matched to a (Z_0) 50 Ohm line with a quarter-wave transformer.

The grounded coplanar line has a spacing to ground of 0.1 mm.

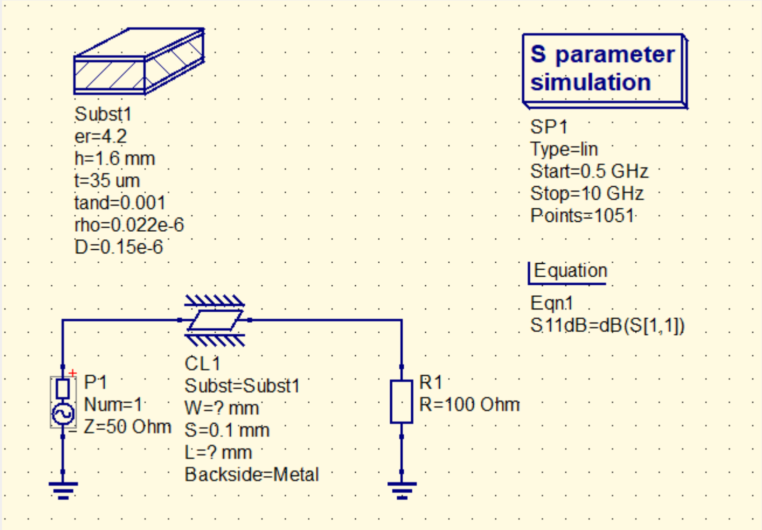


Tip: use “Tools” -> “Line calculation” to determine W,L

Exercise 5 – Co-planar Quarter-wave transformer

To do:

1. Determine the width and length of the grounded coplanar line transformer optimized for *f*=1 GHz.
2. Plot the reflection coefficient Γ (=S_{11}) versus frequency (linear and dB scale).
3. Which line is less lossy?
   The microstrip line of exercise 4, or this grounded coplanar line?



Tip: use “Tools” -> “Line calculation” to determine W,L